FIFTEEN YEARS OF EXPERIENCE WITH COMBINED HEAT AND POWER IN JAMESTOWN, NEW YORK

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INTRODUCTION

This paper addresses the development and operation of the Jamestown Combined Heat and Power (CHP) District Heating System in the City of Jamestown, New York. The conception of the system through the initial feasibility studies is discussed, followed by the development of the system through phased implementation and the current status of operation. The planning aspects that contributed to the successful development of this system are highlighted and the customer savings are cited.

The Jamestown CHP/District Heating (DH) concept was a result of a preliminary feasibility study, financed by the New York State Energy Research & Development Authority (NYSERDA) in October of 1981. The study examined the potential of a CHP/DH system to economically supply the downtown area of Jamestown with thermal energy from the municipal electric plant. The results of the study were promising, indicating the technical and economic viability of the project. In light of the positive findings, a comprehensive second phase study was contracted in order to develop the necessary information for a final decision. The objectives of the second phase study included an engineering reference design as a basis for the financial analysis, a marketing program, a final design, the engineering bid and specifications, the basis for the financial instruments for project financing, and a project implementation plan. This study was financed by NYSERDA and the City of Jamestown. Based on the favorable results of the feasibility studies, the City of Jamestown committed to build a pilot system during the summer of 1984 and expand it to include selected buildings in the downtown core area during the following year.

SYSTEM DESCRIPTION

The Jamestown DH system consists of three major components: the CHP plant, the transmission and distribution network, and the participating buildings or customers. Each component is addressed individually in the following subsections.

CHP Plant

The 50 MW Carlson Generating Station was selected as the central energy source for the Jamestown CHP system. The power plant includes four coal-fired boilers and two steam driven turbine-generator units (Units 5 & 6), both with General Electric non-reheat turbines. Unit 6 was selected for CHP modification considering its larger heat output and relative ease of retrofit to cogeneration. This turbine is a 25,000 KW, 3,600 rpm, 15 stage single-flow condensing unit, designed to operate at 850 psig steam pressure, 900°F temperature, and 3.5 inches Hg condenser pressure; it has a rated throttle flow of 238,072 lbs/hr. Extraction steam for regenerative feedwater heating is taken from four extraction points. The turbine has one blanked-off extraction point at the 11^{th} stage. The feedwater heating cycle consists of four closed and one open feedwater heaters with makeup to the cycle through the condenser hotwell. Steam is extracted from the blanked-off 11^{th} stage turbine extraction for use in a new district heat exchanger. Higher loads are served with additional steam from the auxiliary steam header and used in the existing auxiliary heat exchanger that is arranged in series with the new district heat exchanger (Figure 1). Single purpose efficiency for Unit 6 was 26.9%. After unit conversion to CHP operation, the efficiency increased to 32.5%, a 20% improvement. Modifications to the turbine were not required since the redistribution of extraction flows is minimal and all existing feedwater heaters remain in service without modification.

During peak heat load operation, the return water temperature is 160°F with a DH water supply of 250°F. The DH water flow-rate during peak load conditions is 498,000 lbs/hr. The maximum extraction flow available from the turbine's 11th stage provides heating for 379,000 lbs/hr of district circulating water to 210°F. At the maximum heat load conditions, 119,000 lbs/hr of DH water bypass the district and auxiliary heat exchangers. The 379,000 lbs/hr of 210°F effluent water from the district heat exchanger is passed through the auxiliary heat exchanger. This increases its temperature to above 250°F, so that when mixed with the 210°F, 119,000 lbs/hr bypassed water will produce a total flow rate of 498,000 lbs/hr at 250°F.

The district heat exchanger operates throughout the year, providing hot water for both space heating and domestic use. The auxiliary heat exchanger operates about one third of the year. The maximum operating pressure of the district heat exchanger is about 20 psia; the maximum operating pressure of the auxiliary heat exchanger is 60 psia with a maximum steam flow of 18,900 lbs/hr.

Transmission & Distribution Network

The transmission and distribution network transports DH water from the central plant to the customers and back. It is an underground two pipe closed system with a maximum operating pressure of 232 psi and with pumps sized for a total design discharge pressure of 140 psi. The piping is sized for a maximum velocity of 8 ft/s, based on the peak load supply and return temperatures of 250°F and 160°F.

The prefabricated conduit system consists of a thin wall carbon steel carrier pipe, polyurethane insulation, polyethylene casing, and a leak detection system. The leak detection system combines alarm and fault locator capabilities and is built into the conduit during manufacture to protect the system and facilitate service.

The DH piping is installed in shallow trenches requiring minimal excavation and no shoring. The conduits are laid directly in the trenches on a sand bed. There are at least 6 inches clearance between conduits and between each conduit and the adjacent trench wall. A homogeneous layer of stone-free sand is used to cover the conduits with a surface pavement on top.

Figure 2 presents the transmission and distribution network of the Jamestown DH system. The system development is described in a subsequent section, were the three phases of implementation are individually addressed.

Buildings

The building conversions to DH depended largely on the existing individual heating systems. The design philosophy for the building retrofits is based on the following considerations:

* A plate-type heat exchanger is used in each building to transfer heat from the DH water supply to the building distribution system. This is necessitated by the high temperatures and pressures in the DH distribution network.

* The DH water supply temperature varies according to outdoor temperature, from a maximum of 250^{o}F, on the design day (3^{o}F outdoor temperature), to approximately 170^{o}F during the summer months. Therefore, the building heating system distribution temperature must also be reset from the outdoor temperature.

* Building systems operating temperatures were selected to optimize the size of system components, producing maximum temperature differentials between supply and return.

Conversion of two-pipe steam heating systems to DH was the most prevalent building retrofit in the City of Jamestown. A plate & frame heat exchanger replaced the existing boiler as a heat source. Existing steam and condensate piping, wherever possible, were used to form a closed water loop, with the installation of circulating pumps, expansion tank, and air removal system. All steam traps were removed and air vents were installed at system high points.

Conversion of a gas-fired hot air heating systems involve the installation of a new hot water heating coil in the return air duct, along with an associated plate-type heat exchanger and closed loop hot water circulating system. In instances where a significant amount of outside air was used, a pre-heater hot water coil was installed in the outdoor air supply duct.

Existing hot water heating systems were the simplest and most cost effective to retrofit. In most cases, it merely required the installation of a plate-type heat exchanger.

The conversion and interconnection of all DH customers was timely and economical. This is mainly attributed to the extensive bid packages, which introduced in detail the various concepts of individual heating systems conversion to DH, and to the training and consultations furnished by the consulting engineer.

SYSTEM DEVELOPMENT

The successful development of Jamestown CHP/DH System is a result of the strong support from the City, the BPU, and NYSERDA, and the technical expertise and well orchestrated effort of the consulting engineer. The overall cooperation and strong community support for the project enabled local officials to enthusiastically promote the system, to obtain financing, and to meet an ambitious construction schedule.

Parallel development of the three main system components, power plant, piping network, building retrofits, was necessitated by the inflexible schedule. Work had to be completed by the end of the summer in order for the system to be operable during the start of the heating season.

Phased Implementation Philosophy

The objective of phased implementation is to develop the system in stages, spreading the capital expenditures in incremental investments over the development period and allowing the system to generate revenues to offset the capital investment. CHP/DH in Jamestown is developed in three phases, starting with a pilot system in the first phase, a core system in the second phase, and planned annual growth in the third phase. A pilot project initiated the effort in 1984, which eventually was expanded to a core system in 1985-1986, and has been growing ever since.

The purpose of the pilot project was to impart valuable experience in construction and operation to the local DH officials prior to embarking in a larger venture. The pilot system was also used as a marketing tool to attract skeptic customers. The authorization for the pilot system development was given in June 1984, with actual construction commencing in August and operation in November of the same year. The pilot system served four buildings.

The second phase of DH development in the City of Jamestown involved the retrofit and interconnection of 15 additional buildings the next two years (1985-86), after an aggressive marketing campaign. An extensive transmission system was installed, as part of the second phase development, providing the foundation for future growth. The third phase is ongoing and involves the planned annual growth of the system. This phase capitalizes on the existing network and merely requires the retrofit and interconnection of new customers, along this transmission line. Currently the system services 60 customers.

Marketing

The installation of the pilot system in 1984 created a public awareness which, coupled with the marketing activities, replaced the initial skepticism with enthusiasm for DH and its benefits. The marketing aspects of CHP/DH development in the City of Jamestown involved the combined efforts from the Mayor's Office, the Board of Public Utilities (BPU), other city officials, and the consulting engineer.

Numerous public and private meetings were scheduled with prospective core customers in order to educate them and discuss the advantages of DH for their buildings. A marketing campaign through the media, newspapers/ magazines, radio, and television was used to establish a public consciousness and acceptance, offering evidence through the operation of the pilot system. Brochures were prepared to complement this effort. The marketing venture targeted a diverse customer base, including schools, churches, hotels, hospitals, and retail, office, residential and industrial customers. An ad hoc committee consisting of representatives from:

* major customers and contractors,
* the Manufacturers' Association,
* the Department of Economic Development,
* the Department of Industrial Development,
* and the Department of Public Works,

was formed, under the sponsorship of the Mayor's Office and the BPU to develop a complete community awareness and involvement.

As part of this coordinated effort, the consulting engineer examined prospective customers and presented them with economic packages indicating conventional heating costs, DH costs, and anticipated savings. The benefits and advantages of DH were reiterated. Once a potential customer expressed interest in participating in DH, the consulting engineer was responsible for the conversion of their heating system to DH.

Ownership

Centralized energy projects have exhibited an entire spectrum of ownership structures, which can be classified as either private or municipal. The municipal alternative was selected based on the minimal impact by regulatory constraints. The City of Jamestown presented a distinct advantage over most other localities which have instituted DH systems, because it already operates a municipal electric plant. This electric utility is experienced in dealing with the regulatory environment and is attuned to the City's needs and procedures. The existing structure of the Jamestown Board of Public Utilities (BPU) presented a unique opportunity for the City to institute a DH system which is fully responsive to the interest of the City, with only limited additional procedural, administrative, and managerial costs. The Jamestown BPU has existing authority to use public right-of-ways. Other important factors in the selection of municipal ownership include the federal and state tax-exempt status, and the customer acceptance and trust of municipalities over profit-oriented, private entities.

SYSTEM ECONOMICS

The positive economic analysis results served as the cornerstone for the development of the Jamestown CHP/DH System. The economic analysis was performed from the viewpoint of municipal ownership, utilizing its distinct advantages. The analysis determined the annual carrying charges for the system and the unit cost of district heat. The analysis employed the required revenue approach to determine the necessary charges for DH sales. The method used was to develop the total system costs and compare these costs with the total quantity of heat sold to determine the minimum required charge for DH.

The operating expenses for the DH system were comprised of replacement electricity costs, pumping costs, O&M personnel, O&M materials, and steam costs. The replacement electricity cost is charged against the DH system to compensate for the reduction in electrical output caused by the DH steam extraction requirements.

Rates

The initial charge for DH was set at $7.00/MMBtu. This rate was a direct result of an economic analysis, using a detailed cash flow. It allowed the utility to pay back the debt and the customers to experience energy savings. A rate of $6.00/MMBtu was instituted for large users in 1990. Large user status is granted when the monthly consumption exceeds 300 MMBtu's. The two rates remained constant until 1991, when a 10% increase was approved by the Board of Public Utilities. The current rates are $9.00/MMBtu for small users and $7.50/MMBtu for large users. A peak demand rate is currently under consideration, with an incremental use discount. The comparison of the average DH rate versus the individual customers self-production cost of heat is presented in Figure 3.

Financing

In the context of municipal ownership, the normal source of funding for a DH project is obtained through the issuance of long-term revenue or general obligation bonds. A long-term municipal bond offers a fixed interest rate over the life of the project. The volatility and relatively high levels of interest rates on long-term obligations, at the time, led to the development of a broader spectrum of tax exempt alternatives, including short-term and floating rate longer term instruments. Short-term tax exempt alternatives afforded the opportunity to take advantage of the substantially lower interest rates during the construction period. However, short-term bonds were available if long-term bonds were intended to be the ultimate debt. A short-term debt is considered to be any debt with a maturity of less than one year.

The Phase I development of the Jamestown DH System, involving the institution of a pilot system, was financed with short-term bonds. The later phases were financed with long-term bonds, including the refinancing of the first phase.

SYSTEM BENEFITS

The benefits derived from the implementation of a CHP/DH system are multifaceted. CHP benefits include environmental advantages, Demand-Side Management application, customer savings, and potential for urban economic revitalization. Customer savings and environmental advantages are among the most important by-products of CHP/DH development in Jamestown, with the DSM application become increasingly recognized. An advantage specific to the Jamestown DH system design is the elimination of the chemical water treatment without corrosion consequences.

Customer Savings

The customer savings during the fifteen year period are summarized in Figure 4. During the period of 1984 through 1998 the DH customers have experienced a cumulative savings of $7.1 million from participating in this CHP/DH system instead of operating their individual equipment. The savings rate increases with any increase in the price of fuel. Customer savings are expected to rise in the future as the system grows with minimal capital investment.

Environmental

CHP/DH is an energy conservation measure noted for increased thermal efficiency, reflected in the energy savings of connected customers. Higher thermal efficiency corresponds to more useful energy output per given quantity of fuel input. In addition, centralization of load eliminates the sharp spikes in demand of individual buildings. These load spikes result in the over sizing of equipment, which are selected for peak conditions and fail to provide optimum performance at other conditions. Load leveling permits the plant to operate at reduced peak and at longer sustained intervals, which contribute to enhanced energy utilization. All this translates to lower emissions and consequently reduced environmental pollution. Boilers used by individual customers cycle on and off producing a loss in efficiency, partially associated with the incomplete combustion of fuel. The continuous and efficient operation of the CHP plant reduces the carbon monoxide and hydrocarbon emissions, which are characteristics of incomplete combustion. Up-to-date, 110 individual boilers have been shut down by the customers that were connected to the DH system.

Demand-Side Management Application

The substantial increase of demand for electrical power over the past years, along with the enormous costs associated with the addition of new capacity have led to the emergence of Demand-Side Management (DSM) programs to address the disparity of peak loads versus the base loads, as well as their seasonal variation. In general, these programs target demand reduction by removing inefficiencies, a more economically viable option than the installation of new capacity.

CHP/DM offers potential for DSM application by replacing electrical heating systems. Electrical systems are converted to hot water and interconnected with the DH system. This conversion to district service eliminates the electrical demand for heating. This application of DH is significant for the City of Jamestown, considering the winter peaking characteristics of the electrical utility. Up-to-date, 250 Jamestown apartments have been successfully converted from electric heat to hot water based district heating.

Future Expansion

The system has been expanded every year and now serves 60 downtown buildings. Additional expansion are planned and implemented every year. Currently one satellite boiler plant is in operation supplying residential customers located far from downtown. In addition, the buildings of the Jamestown Community College (located at a distance of two miles from downtown) are connected with piping into another satellite DH system. A mile and a half long pipeline connecting the downtown district and the industrial corridor is planned.

Currently, the Jamestown Board of Public Utilities is repowering the Carlson Generating Station with a GE LM-6000 gas turbine (Figure 5). The repowering permits to increase the plant capacity to 90 MW and increase the CHP/DH efficiency up to 90%.

CONCLUSION

The successful development of CHP/DH in the City of Jamestown, New York, is the result of a well coordinated effort, starting with the system's conception to its operation and growth. The promising findings of the initial feasibility study were pursued further in a second phase detailed study, used to make the final decision. The system was implemented in stages, starting with a pilot project that was used as a marketing vehicle, demonstrating the system's benefits, savings and reliability. A coordinated effort among the Mayor's Office, the BPU, and the consulting engineer, produced an effective marketing campaign. Meetings and advertising created a public awareness, which eventually led to an extensive community participation.

The consulting engineer met with the perspective customers, providing individualized attention and marketing leverage. They produced comprehensive bid and specification packages and trained the contractors in the retrofit process for the various heating systems. The design and planning of the consulting engineer produced a cost effective development, with phenomenally low installation and retrofit costs.

The system ownership and financing capitalized on the advantages offered by the municipal avenue. The BPU promotes and operates the Jamestown CHP/DH System. This enables the City of Jamestown to control the major sources of energy: electricity and heating. The municipal control of these energy sources is used as an economic development tool by the city to attract new business.

The future of DH is Jamestown appears very attractive considering the development of a system with twice the capacity of the present load. Any system growth beyond the existing customer base is expected to enhance the economic operation of the system.

<u>Biographical Sketch of Dr. I. Oliker, P.E.</u>

Dr. I. Oliker, the President of Joseph Technology Corporation, has been involved in CHP/District Energy development, design, and construction in the U.S., former USSR, Korea, and China for over 30 years. He received his master and Ph.D. degrees in CHP/DE from the Moscow Engineering Institute. He is licensed professional engineering in ten states. He is the past president of the International District Energy Association and the recipient of the honorable Norman R. Taylor Award. He is the author of 140 technical papers, 7 books and 15 patents.